Detailed Stratigraphic Study of the Rose Run Sandstone in Coshocton, Holmes and Tuscarawas Counties, Ohio: A Potential Carbon Dioxide Injection Horizon

Senior Thesis

Submitted in partial fulfillment of the requirements for the

Bachelor of Science Degree

At The Ohio State University

2011

By

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2011

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Acknowledgments

I would like to thank Ron Riley and Chris Perry at the Ohio Geological Survey for giving me the opportunity to work with them and allowing me to use all the resources at their disposal. I would also like to thank Dr. Cole for his patience and guidance.

Abstract

This study focused on using geophysical well logs to analyze the Rose Run sandstone, a member of the Knox group, as a possible candidate for carbon sequestration. The three main members of the Knox group are the Beekmantown dolomite, which overlies the Rose Run sandstone, which overlies the Copper Ridge dolomite. In Holmes, Coshocton, and Tuscarawas counties the Knox dolomite is truncated by an unconformity and overlaid by the Wells Creek shale. The Rose Run sandstone in the study area has a sufficient capacity of porosity (4%) to allow for injection and migration of supercritical brine. The thickness of the Rose Run is sufficient to act as a natural storage unit. The overlying Wells Creek dolomite is at least 10 feet thick and impermeable making it an excellent cap rock, preventing upward migration of CO_2.

Introduction

Greenhouse gasses in the atmosphere are responsible for trapping radiant heat from the sun (NETL, 2010). This is a natural and beneficial phenomenon that plays a key role in climatic, and therefore ecologic, preservation (NETL, 2010). One such greenhouse gas is CO_2, which is given off naturally by volcanic activity, animal respiration and naturally occurring fires (NETL, 2010). However, CO_2 is also generated from man-made sources, like the combustion of fossil fuels for energy production and transportation (NETL, 2010). With the growth of industry and commercialization these manmade sources also increase and CO_2 levels grow with them. According to the Energy Information Administration, global energy producing sources of CO_2 release 34 billion tons of greenhouse gasses each year (NETL, 2010). Most scientists contribute this rate of production to be the cause of global climate change today (NETL, 2010).

Ordinarily CO_2 in the atmosphere is absorbed by plants and other photosynthetic organisms, or fixed in oceans, biomass and soils (NETL, 2010). The Department of Energy (DOE) is also attempting to implement a means of filtering CO_2 from the combustion process and transporting it to an area where it can be stored in natural geologic reservoirs (NETL, 2010). Thus far, there are five possible formations which are thought to be suitable for CO_2 storage: saline formation, oil and gas reservoirs, basalt formations, un-mineable coal areas, and organic rich shales (NETL, 2010). This study focuses on the use of oil and gas reservoirs in eastern Ohio.

Oil and gas reservoirs are a good candidate for carbon storage since they have already been proven to store oil and gas for millions of years and they are widely distributed across the world. They typically consist of a permeable storage rock formation, like sandstone, overlain by an impermeable caprock, such as shale, limestone and anhydrite (Benson and Cole, 2008). Supercritical CO_2 is injected into the reservoir where the pressure and temperature conditions would maintain it in a supercritical state (Benson and Cole, 2008). Since the CO_2 is still less dense than the surrounding rock, it will rise until it is blocked by the confining caprock interval (Benson and Cole, 2008). Using these reservoirs as CO_2 storage sites could also serve as a means of CO_2 enhanced oil recovery (Benson and Cole, 2008).

Several key issues must be addressed when selecting suitable subsurface storage formations. These include but are not limited to the nature and integrity of the cap rock, the porosity and permeability variations within reservoir rock, reservoir rock thickness and lateral extent, mineralogy and brine composition (Benson and Cole, 2008). The objective of this study is to analyze an oil and gas reservoir already known to be greater than 5000 feet deep and regionally extensive, the Rose Run sandstone.

Regional Structural and Stratigraphic Setting

The study area consists of Holmes, Coshocton and Tuscarawas Counties in eastern Central Ohio. Regional structure of the Knox unconformity shows an east by southeast dip of approximately 100 feet per mile in the study area (Riley et al, 1993).

The Knox Dolomite consists of the following units in ascending stratigraphic order: Copper Ridge dolomite, Rose Run sandstone, and Beekmantown dolomite. The Copper Ridge dolomite is crystalline, vuggy and impermeable (Riley et al, 1993). The Rose Run sandstone directly overlies the Copper Ridge dolomite throughout the study area. It has a gradational contact which is not clearly discernable in some of the southern areas with geophysical logs (Wickstrom et al, 2005). The Rose Run sandstone is interbedded with dolostone lenses and the top of the Copper Ridge dolomite is placed at the base of the lower most sandstone unit (Wickstrom et al, 2005).

The sands that make up the Rose Run sandstone were mixed in with the carbonate deposits along a shallow marine shelf in the Middle Ordovician (Riley et al, 1993). The widespread Knox unconformity was deposited when sea levels dropped (Wickstrom et al., 2005). The formation of the Rose Run between two carbonate layers is a result of peritidal deposition (Riley et al, 1993).

The Rose Run sandstone unit consists of subrounded to rounded, very fine to medium grained poorly to moderately sorted grains of quartz arenites, arkoses and dolostones (Janssens, 1973). Grains are white or light grey and the layer is interbedded with thin lenses of nonporous dolostone (Wickstrom et al, 2005). The dominant cementing agent in the Rose Run sandstone is dolomite, though clay, quartz and feldspar cements can also be found (Janssens, 1973). Rose Run sandstone can be found throughout eastern Ohio. On a local scale, samples show low-angle cross bedding and ripple marks (Wickstrom et al, 2005). In some samples polygonal mud cracks can be identified (Wickstrom et al, 2005).

The Rose Run sandstone lies directly underneath the Beekmantown formation with an exception to the western edge of the subcrop where truncation at the unconformity has eroded the Beekmantown formation (figure 1). The Lower Wells Creek formation or the Black River group directly overlies the Rose Run and serves as the immediate confining interval (figure 2). In the areas where it is overlaid by Beekmantown, the top of the Rose Run is placed at the top of the first well developed, porous sandstone layer underlying a nonporous dolomite (Wickstrom et al, 2005). In other areas the top of the Rose Run is placed at the top of the first porous sandstone layer that underlies an impermeable interbedded shale and dolostone of the Wells Creek or by the impermeable, nonporous dolostone of the Black River (Wickstrom et al, 2005).

Methods

This study was divided into three main phases: 1) digitizing the subsurface well log data, 2) organizing the data for analysis and 3) interpreting the data. The geophysical oil and gas well logs used for the subsurface data are predominantly paper logs dating back as far as the 1960s. In order to organize them for easier analysis, they had to be scanned and then digitized into a Log ASCII Standard (LAS) file format. The data in an LAS file can be displayed as a log by programs like Geographix or viewed and edited as a text file. As an LAS file the data in well logs can be quantified and quickly correlated to other logs. This allows us to make maps, cross sections, stratigraphic columns and a number of other useful analyzing tools to determine porosity and heterogeneity in the subsurface bedrock of the study area.

When an oil and gas well is drilled in Ohio, a logging company is contracted to run wireline log readings of the well. The owner of the well is then required to send a paper copy of all well logs to the Division of Minerals Resource Management (DMRM). The well logs are then transferred to the Division of Geological Survey (DGS), which is the state repository for oil and gas well logs. Since the digitization of the logs has become common practice, these logs are scanned soon after arrival using a program called Neuralog with a Neurascanner brand scanner and then archived for future reference. The scanned copies of the logs are saved as raster images known as Tagged Image Files (TIF) files.

When a certain well log is desired for a project, it will be digitized into a vectorized LAS file. This process also uses the Neuralog program to create vector data that overlays the digital raster image. Depth and scales for geophysical instruments are recorded. At this point it is decided which geophysical curves to use. In this study gamma ray, caliper, bulk density, neutron, neutron porosity and photoelectric effect curves were used if they were available. Not all logs were made by the same logging company and certain types of data were not available for some wells.

Once the data are digitized and the LAS files are stored into a computer database, Geographix software is used for posting well locations, creating cross sections, correlating formation tops from well to well, and generating structure and isopach maps. For each well the top of each stratigraphic mapped unit is interpreted and the top is recorded. Currently there are over two hundred wells in the database for this study area that were digitized, interpreted, and used in mapping. A stratigraphic cross section was constructed for this study, and six maps were generated for analysis and interpretation of the Rose Run sandstone reservoir.

Results

The structure maps of the Rose Run sandstone and of the Copper Ridge show a clear east southeast dip in figure 4 and figure 5, respectively. In both of these maps the unit is shallower in the northwest and deeper in the southeast. The Rose Run gets 2500 feet deeper throughout the region while the Copper Ridge gets 2850 feet deeper. This eastward thickening of the Rose Run is also seen in an isopach map of the Rose Run (figure 6). Thickness ranges from 50 feet in two areas of the western portion of the outcrop to 120 feet in eastern Tuscarawas County.

After the thickness of the Rose Run is determined, the portions of that thickness with a bulk density (rhob) less than 2.65 g/c^3 is calculated and displayed as figure 7. Throughout the study area thickness of 2.65 g/c^3 or less density sandstone is generally greater than 30 feet.

Figure 8 is an isopach map of the Lower Wells Creek. This map was made to analyze the thickness of the Lower Wells Creek in order to determine suitability as a cap rock for the Rose Run. In the region where the Wells Creek is the upper contact of the Rose Run, there are two areas where the thickness is less than 10 feet.

Discussion

The use of geophysical well logs is an excellent way to get a good description of the stratigraphy at the well site. In areas where a lot of drilling has taken place, the regional stratigraphy can be discerned by examining the data found in the well logs of the area. Figure 1 shows how the geophysical log data correlates to the stratigraphic intervals around the Knox unconformity. Tuscarawas, Coshocton and Holmes counties have approximately 1000 logged oil and gas wells. Of these, more than 200 have been digitized with Neurolog software, and then analyzed with Geographix and included in this study. With this number of samples it is possible to extrapolate the depth and thickness of the Rose Run sandstone throughout the area, as well as the confining interval, the Wells Creek dolomite.

There are some shortcomings to using oil and gas geophysical logs. The drilling depth may not go as deep as desired for this study. The shallowest anticipated depth of the Rose Run is about 5000 feet. There are some oil and gas wells that only go a fraction of that depth. This is likely because those wells were not attempting to tap oil and gas in the Rose Run, but instead trying to reach a shallower reservoir.

In this study only gamma ray, caliper, neutron, neutron porosity (nphi), bulk density (rhob), and photoelectric curves were used. These curves are capable of differentiating the rock type and providing porosity. In some cases, the logging company elected not to use some of these curves in their logs. Usually companies favor one type of log over another. For example, most logging companies use nphi curves in their logs, but some others will use a compensated neutron curve instead. Units and scales are different for the two curves, but both are used with density to determine porosity.

Because of the Knox unconformity the Rose Run sandstone outcrops and makes contact with the confining Wells Creek dolomite (Figure 2). The cross section shown by figure 2 is highlighted in figure 3. This can be seen all along the northeast – southwest strike of the Knox dolomite. Also in figure 3 two dark lines are drawn to outline the area where the Rose Run makes this contact with Wells Creek. In the area just west of the western most line the Copper Ridge dolomite, outcrops at the unconformity. East of the eastern most line, the Beekmantown dolomite outcrops. This can be seen in figure 2 and other cross sections of the area.

Using Geographix it is possible to input the tops of each stratigraphic layer into every individual well log. Geographix can then create a structure map for the desired stratigraphic unit. Figure 4 is a structure map made for the Rose Run sandstone. Figure 4 shows an east southeast dip and the eastern extent of the outcrop. The same process was used for the Copper Ridge dolomite in figure 5. There is more extrapolation in figure 5 because fewer well logs go as deep as the Copper Ridge. With the data on hand, Geographix can calculate the difference between the two structure maps and create a Rose Run isopach map (figure 6).

With the digitized well logs, Geographix can use the quantified log data and represent it over the mapping area. In figure 7 Geographix looked at all the rhob data where density was less than 2.65 g/c^3. It would scan the logs starting at the Rose Run top and stopping at the Copper Ridge top, and calculate the total thickness that has a density less than 2.65 g/c^3. 2.65 g/c^3 correlates to approximately 4% porosity. Throughout the study area thickness of 4% porosity sandstone is generally greater than 30 feet. The area under Tuscarawas County appears to be more uniform in porosity, probably due to fewer analyzed wells in the area. In this study rhob data were used because it was the most uniformly used curve in the study area.

In regards to carbon sequestration, the ability to store supersaturated carbon dioxide relies on the capacity of the reservoir rock and the ability of the overlying cap rock to seal in the rising fluid. Figure 8 is an isopach map of the Lower Wells Creek dolomite. The lower portion of Wells

Creek is denser than the upper portion so the thickness of the Lower Wells Creek represents a minimum sealing capacity. Figure 8 shows the Lower Wells Creek covers the Rose Run throughout the study area and that the thickness varies over the area with a minimum thickness of 10 feet in a few areas.

Conclusions

Based on the geophysical well log data, the Rose Run sandstone is isolated, porous, and accessible. The Lower Wells Creek dolomite acts as a nonporous cap rock with a minimum thickness of 10 feet over the Rose Run. The amount of porous sandstone in the Rose Run is greater than 30 feet in most areas, but varies throughout the region. The thickness is more consistent in the eastern portions of the study area. Access to the Rose Run already exists. There are over 200 oil and gas wells that penetrate the Rose Run. In southeast Tuscarawas County some wells penetrate the Rose Run as deep as 7000 feet.

To maximize the effectiveness of the Rose Run as a carbon dioxide reservoir, the injection would best be placed in Tuscarawas County. The CO_2 brine injection fluid is less dense than the reservoir rock so it will drift upward over time until it is captured under the nonpermeable cap rock. Due to the east southeast dip of the formation more reservoir space is accessible if injected into the deeper eastern portion of the formation.

Potential Future Work

Analysis of geophysical well log data and assessment of structure and stratigraphy on a macroscopic scale sets the stage for a closer look at carbon sequestration on a local scale. Using core samples it may be possible to analyze porosity and permeability in the sample and compare it to the well log data. By making several comparisons it may be possible to make a regional assumption of the porosity and permeability. With these regional conditions it would be possible to make quantitative estimates of the capacity of the reservoir rock in question.

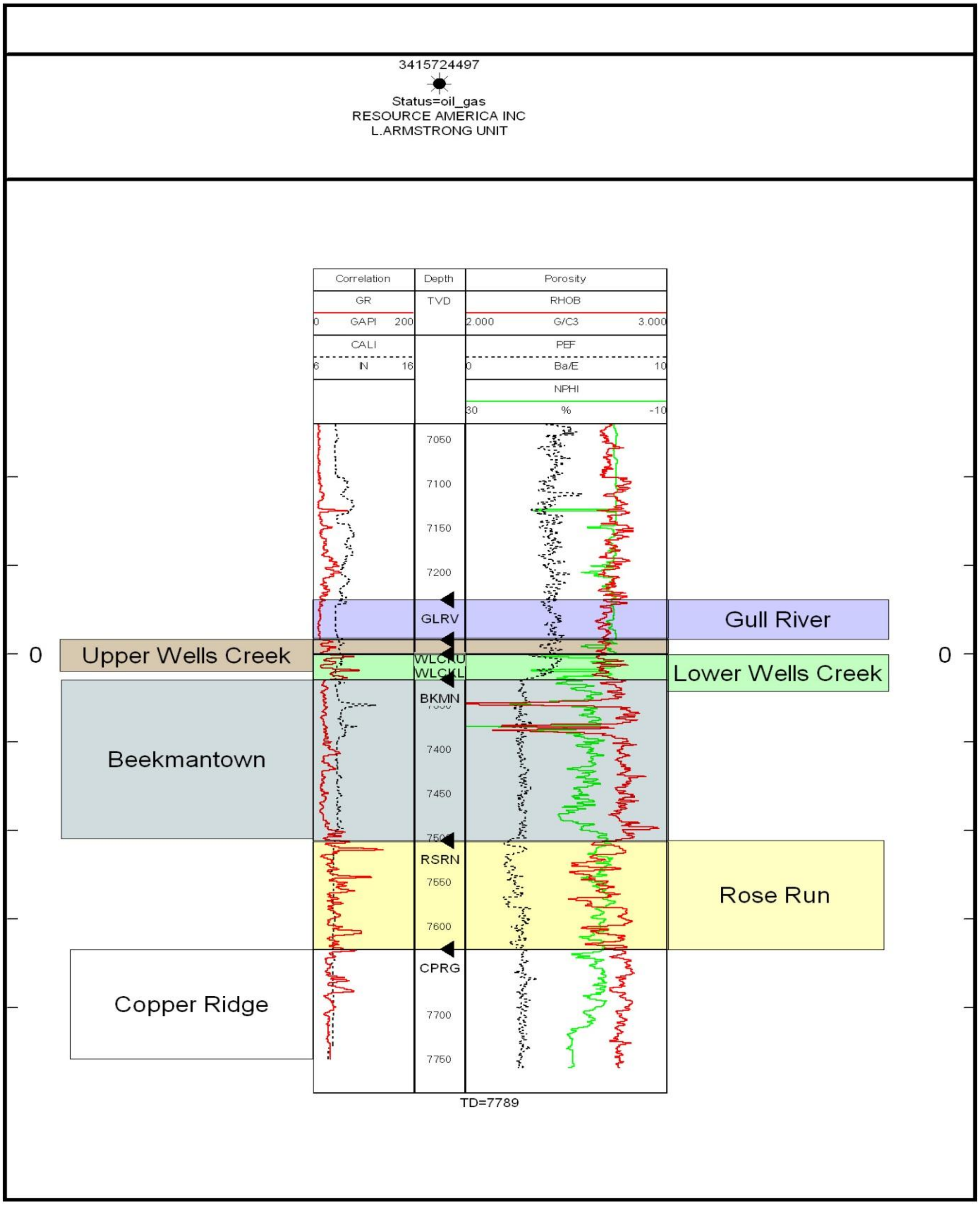

Fig. 1 Stratigraphic column of Knox and Wells Creek dolomites and the associated geophysical well logs

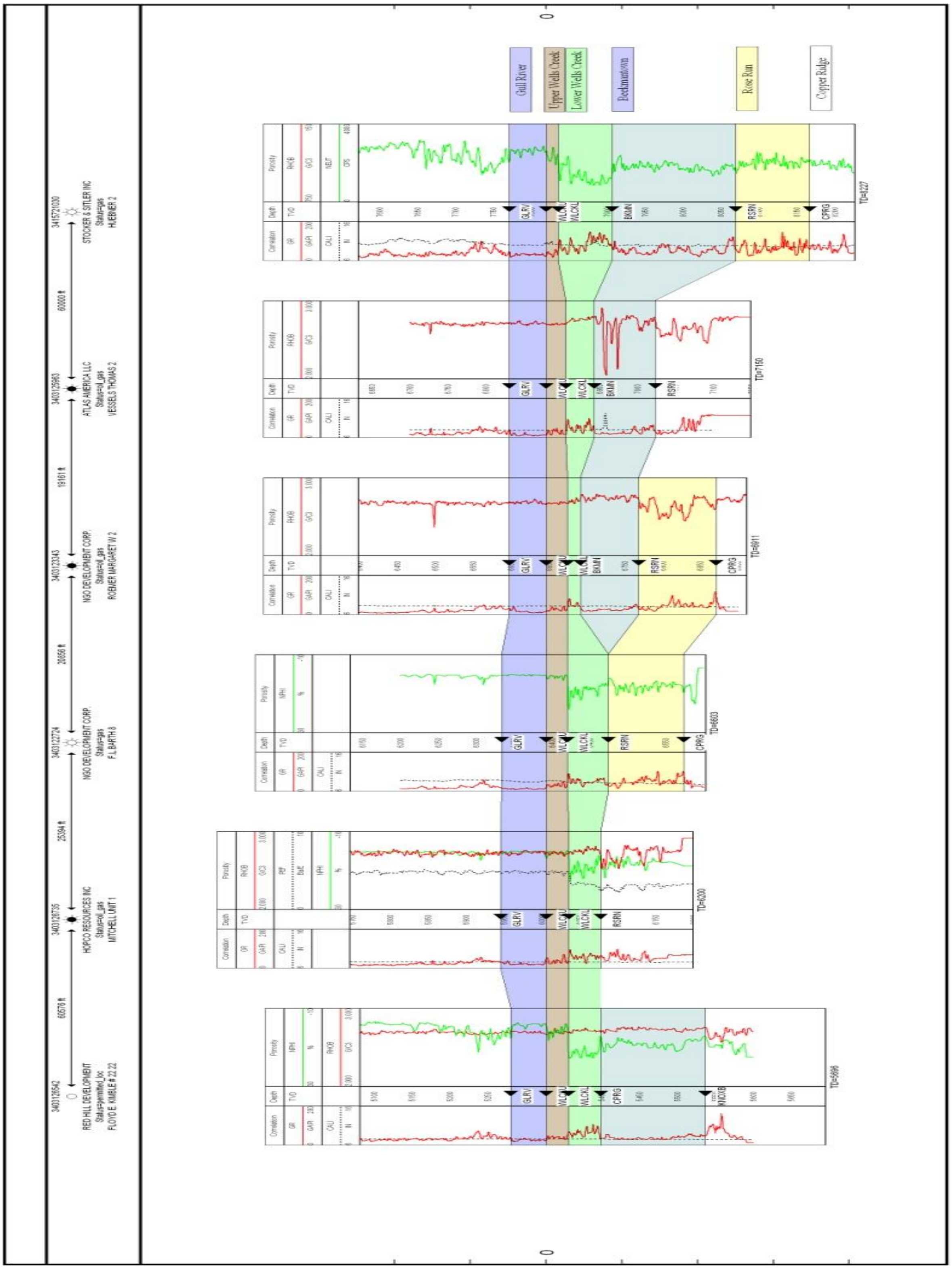

Fig. 2 Stratigraphic east-west cross section

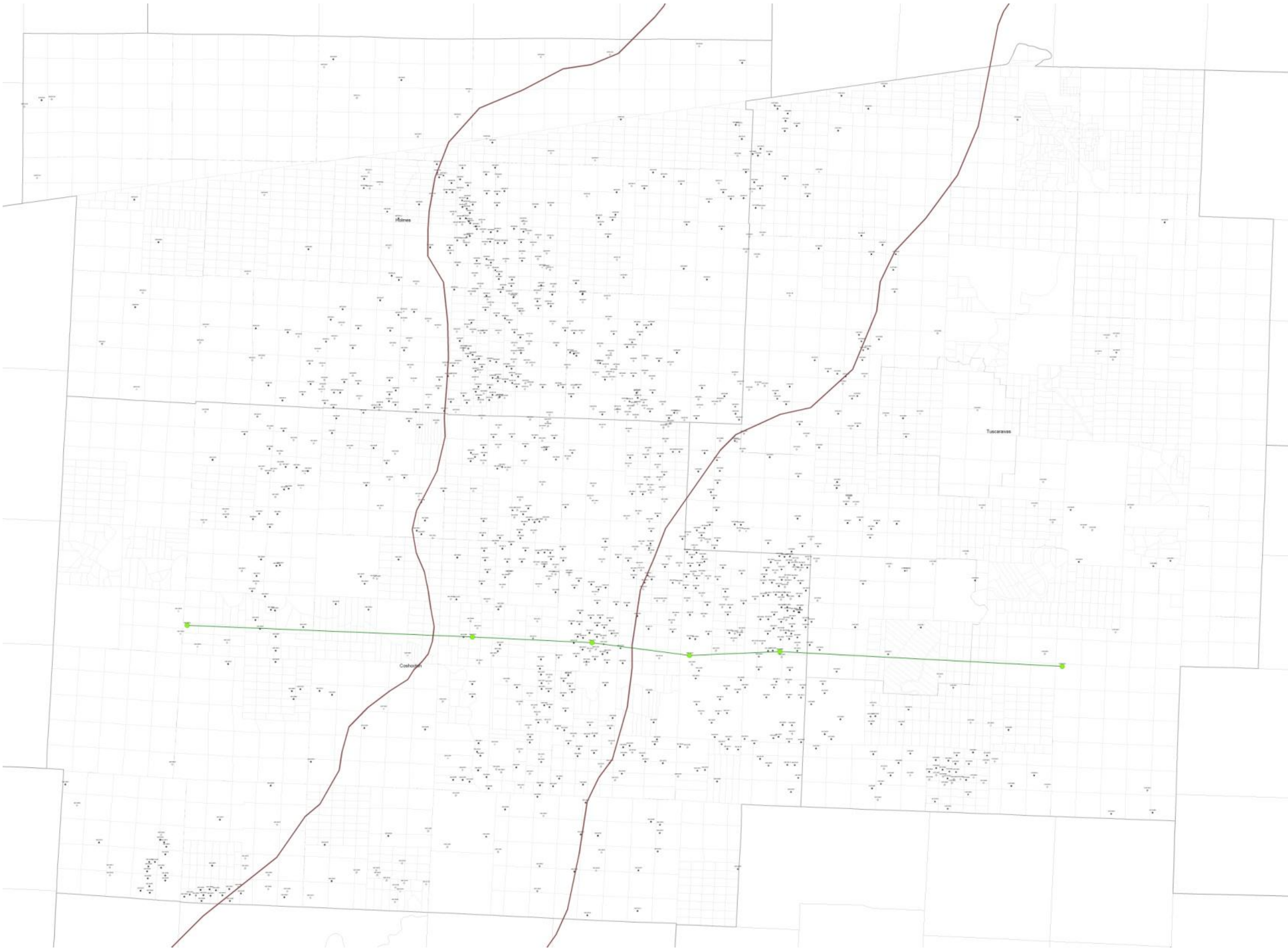

Fig. 3 Rose Run outcrop in Coshocton, Holmes and Tuscarawas counties with projection of cross section shown in Fig. 2.

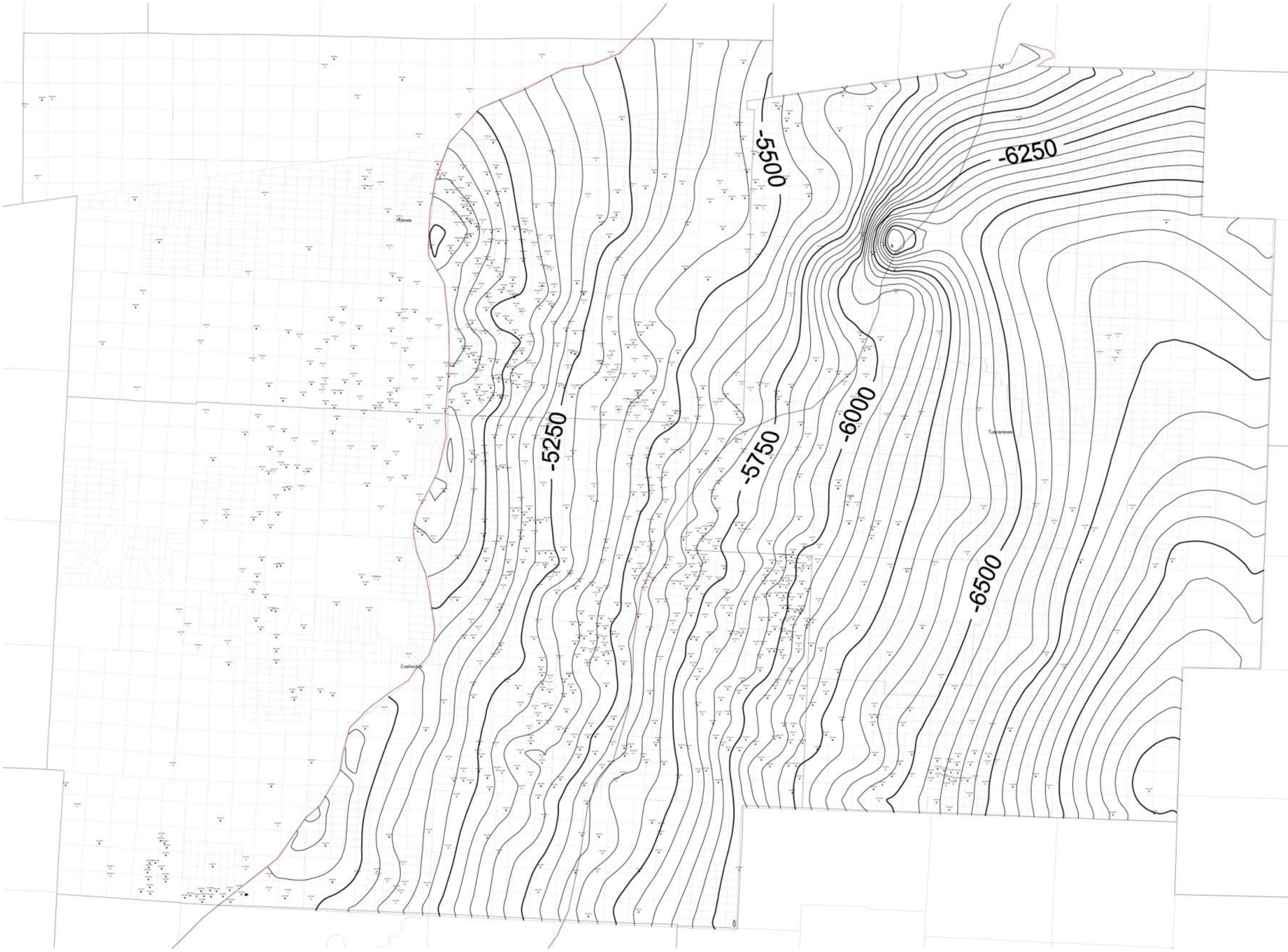

Fig. 4 Rose Run sandstone structure map. Contours measure in feet.

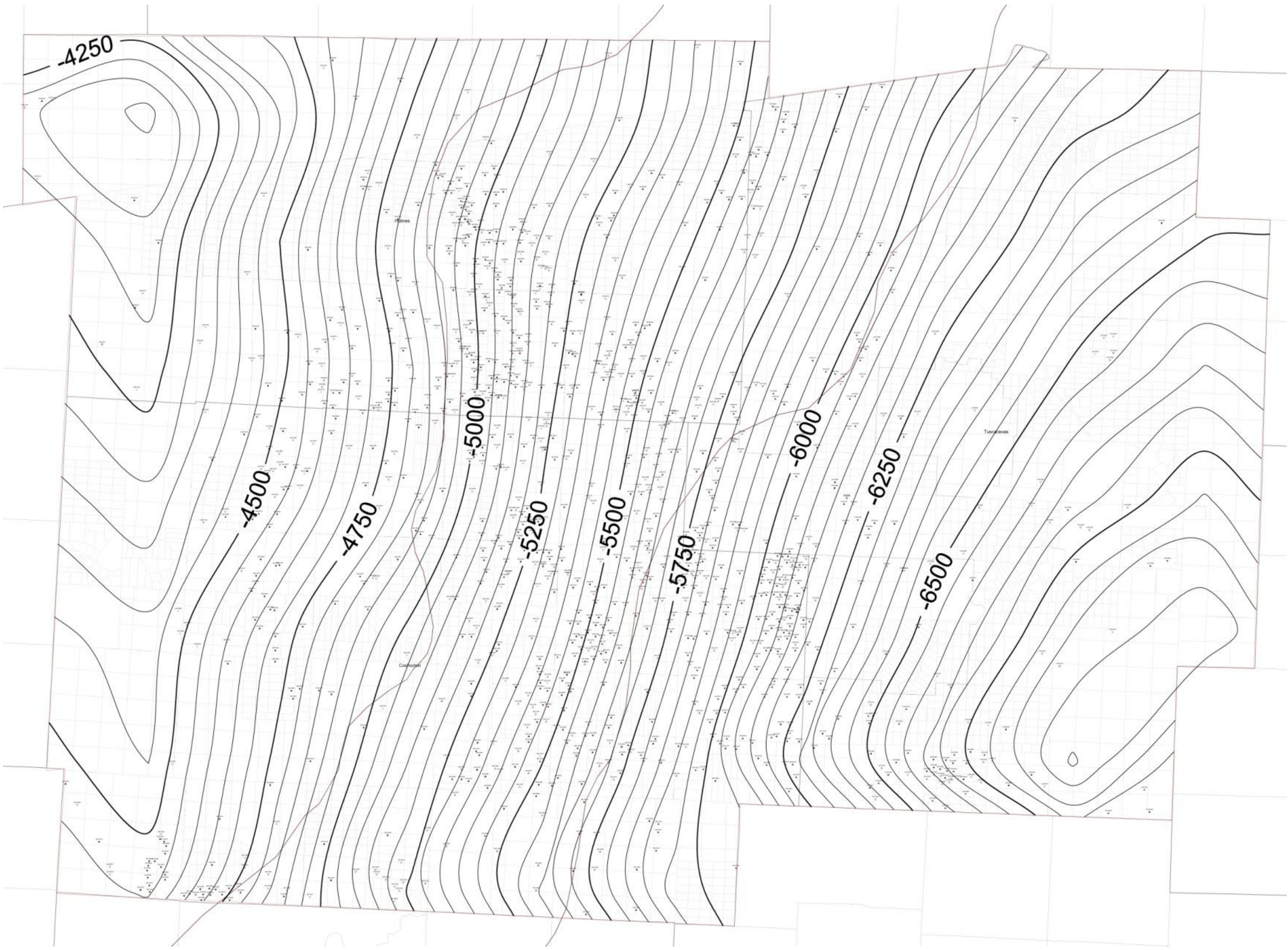

Fig. 5 Copper Ridge dolomite structure map. Contours measured in feet.

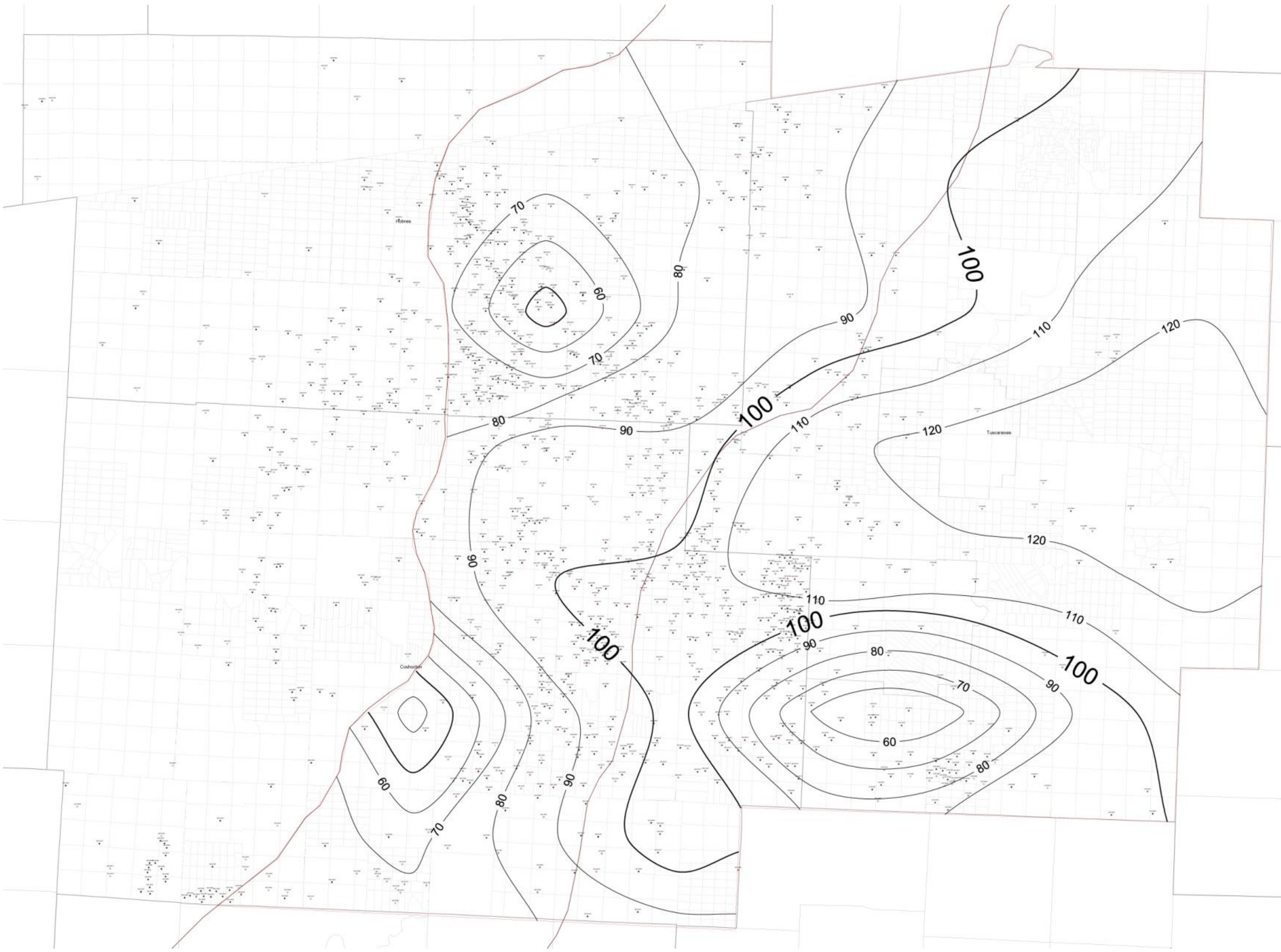

Fig. 6 Rose Run sandstone isopach map. Contours measured in feet.

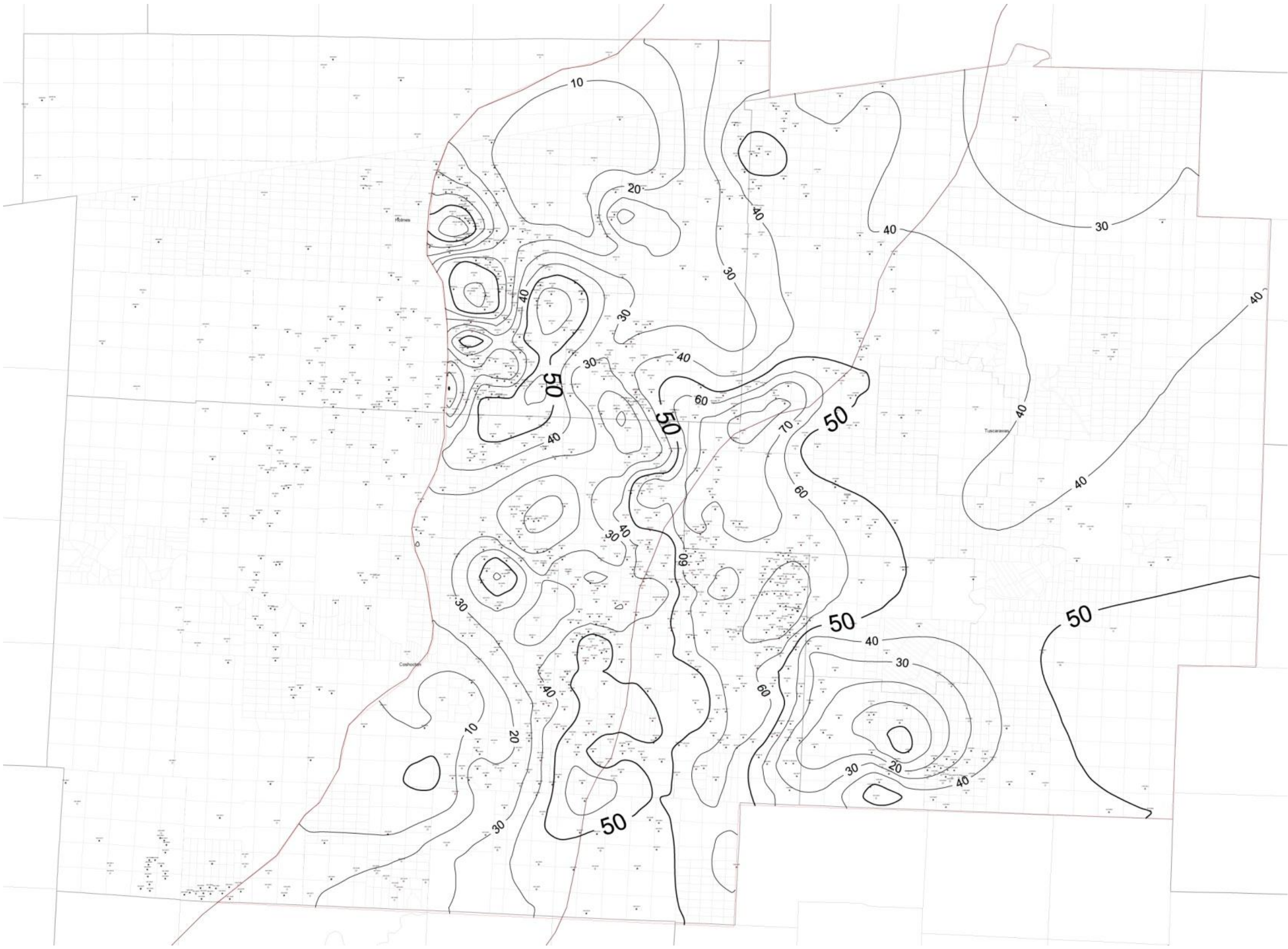

Fig. 7 Thickness of sandstone with rhob < 2.65 g/c^3. Contours measured in feet.

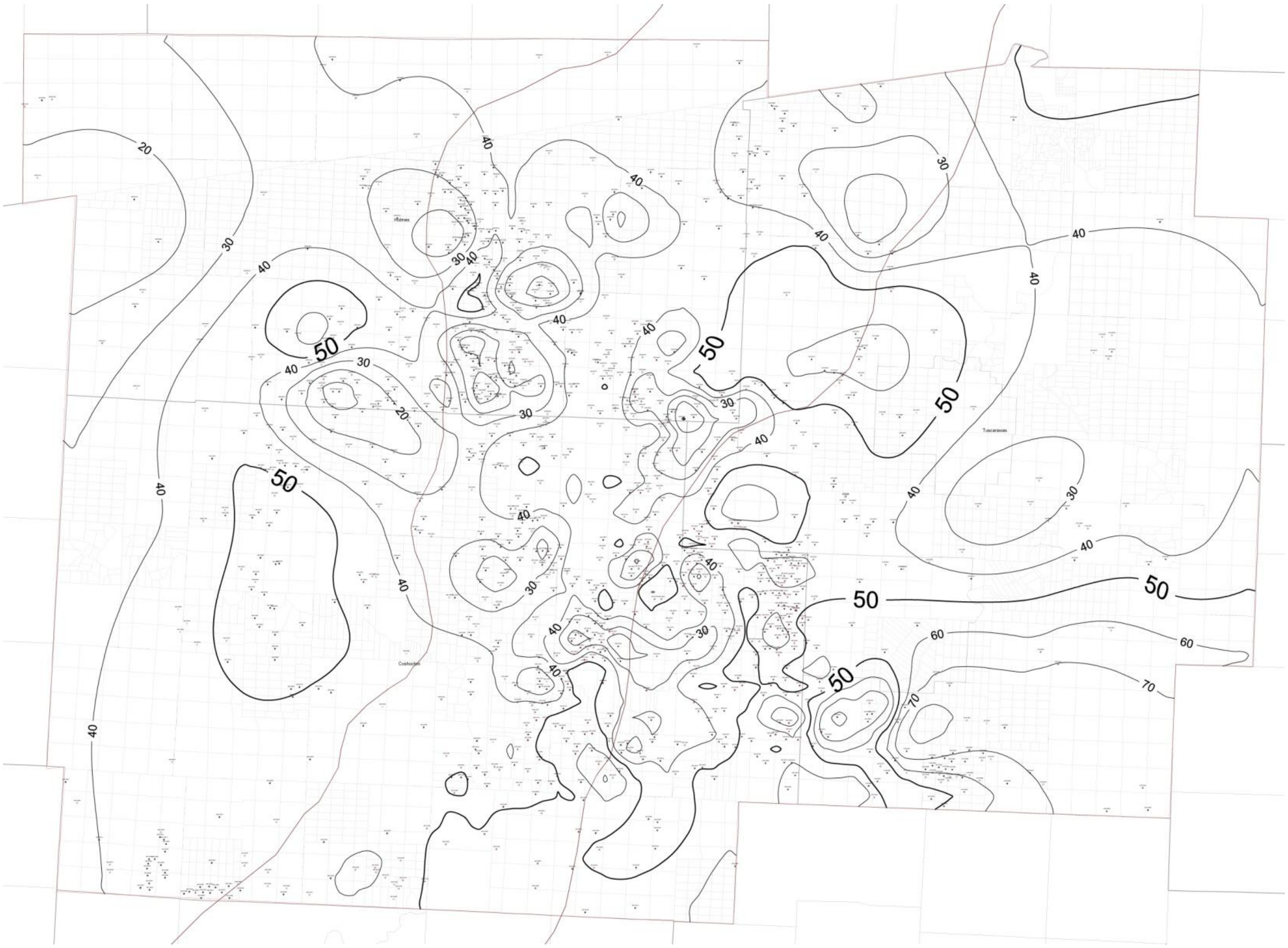

Fig. 8 Lower Wells Creek isopach map. Contours measured in feet.

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